

GWS-0213
COPY 2 OF 27 Grove Street
Winchester, Massachusetts

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Mr. Richard Bissell
Washington 25, D. C.

Dear Dick:

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I am enclosing two pairs of prints showing a schematic lay-out of what I visualize the optical system might be for a [redacted]-inch focal length [redacted] aerial camera covering a [redacted]-degree total field. The scale is 1:5 so that 2 inches on the print corresponds to 10 inches actual size. However, you can scale everything according to the focal length finally decided upon.

After thinking over the requirements following our discussions, I have decided that the use of the shell lens near the image surface is mandatory, together with a pair of correcting elements located near the quartz window. Optical workers will recognize this system as a shell-Schmidt or as a modified version of the Super-Schmidt Meteor Camera. The primary mirror is precisely spherical. Most of the spherical correction is provided by the simple shell, which has concentric surfaces around the center of curvature of the primary mirror. The shell introduces a minor amount of color aberration which is then eliminated by the slightly hyperchromatic pair of correcting elements at the center of curvature. This pair of correcting elements is of the usual crown and flint, with the individual optical powers exceedingly weak, and with one or both adjacent surfaces figured aspherically. It is vital that the shell do as much of the correcting of the spherical aberration of the mirror as it possibly can, not only to minimize the residual off-axis aberrations of the pair of correcting elements but also to make the optician's task easier.

I have sketched in a mirror on the side view to indicate how the optical axis might be directed downward. However, the exact size and location of the mirror must await a detailed study of the configuration.

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It is clear that if a [redacted]-degree total field is to be covered, the primary mirror must be a very large one. I estimate the total weight of the primary mirror to be of the order of 100 lbs. if the necessary precision is to be obtained optically. One can reduce its size appreciably by introducing some vignetting of the extreme rays. The [redacted]-degree total field means that the format for a single picture will be [redacted] inches.

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In order to minimize the weight and size of the primary mirror, I have resorted to replacing the normal circular aperture by a [redacted]-inch rectangular aperture, where the latter is achieved by having the plan view stop in one location and the side view stop in another. This arrangement requires using the off-center portion of the correcting plates as shown in my separate diagram on the plan view at upper left. One

cannot escape making up a large aperture correcting plate anyway, and if accomplished as shown here, two optical systems can be obtained from one overall on-axis optical system, which turns out to be a [REDACTED] length [REDACTED] modified meteor camera. In other words, to cover the large angular field at [REDACTED] we are using selected beams from a basic [REDACTED] system, only part of which is actually in the final camera. It is mandatory that the [REDACTED] basic system be designed and built to perform to a target level in excess of [REDACTED] for any [REDACTED] portion thereof to any part of the field. This would mean roughly that the basic [REDACTED] system must give a circle of confusion of the order of [REDACTED] in any part of the field and that the distribution of light within this circle of confusion be such as to provide a diffraction image for any [REDACTED] portion thereof, from which the target resolution in excess of [REDACTED] lines/mm follows.

Now this optical system for a [REDACTED] is quite a large one and in the making, problems will be encountered that may lead to the design and building of suitable jigs and fixtures, molds and even special machinery. If so large a primary is to be made so thin, the optician will have to have a supporting surface of the same diameter and back radius, which can be of iron, but which in turn will require large grinding and polishing machinery. Hopefully, a pyrex blank can be provided that will minimize the amount of shaping required, but this may lead to a special mold at the glass works and to the tying up of facilities for long periods of time. Indeed, because of the ever-present breakage hazards, one would have to plan for extra blanks and extra optical work.

Obtaining the optical glass blank for the shell-lens may also require time but I have every confidence that the advance in glass technology during the past 10 years will make procurement and fabrication of such blanks quite feasible. Similarly, the ^{cornea} ~~cornea~~ and flint elements of the correcting pair will offer us no problem beyond the fact that a great deal of careful optical work is required, dependent on well designed testing rigs. You will note that I have isolated the quartz window problem and am leaving this window as a plane parallel plate as usual. Quartz is hard to come by in these sizes, and it seems wiser to minimize the fabrication of the thin window by staying to plane parallel surfaces. For one thing with available quartz boules a window as large as required can only be half an inch thick or so.

You will note also that I feel that a focal plane type shutter will be required. If a between-the-lens type were to be used, the primary mirror would have to be all the larger to cover the [REDACTED]-degree total field without vignetting. Perhaps this could be done, but already the primary is as large as I remember the compartment to be. Scaling everything to a [REDACTED]-inch focal length would help, but then I doubt whether you could cover a [REDACTED]-inch film any longer. Hence, a focal plane type shutter goes best with minimizing weight. One scheme would be to have a flexible curtain with spaced reinforcing rods carrying rollers above and below, riding on a track all the way around the primary mirror in endless fashion. The slit would start behind the primary and open up during the accelerating phase, cross the curved focal surface, and be closing while the curtain as a whole is decelerating. Rewind of the shutter would thus be unnecessary and no capping curtain would be needed. There would be plenty of room for accelerating, velocity control and shock absorbing and decelerating. The focal plane shutter would need to be flexible only in the one section, which then permits use of the stiffening

I doubt very much whether a field-flattening toric lens would have to ride on the slit, as we touched upon last week. It appears very possible simply to have the [redacted] inch film follow the [redacted] inch radius of curvature of a spherically surfaced back-up platen. I estimate that the [redacted] inch meridional section would have to stretch about [redacted] inches for the upper and lower edges of the [redacted] inch film to fit the small circle of the spherical platen. The film will stretch some under moderate tension and perhaps enough, but I think edge riders above and below holding the edges of the film down to the curve will do wonders without too much tension. The difference in area of the cylindrical film and spherical platen is small, and a slight amount of buckling is permissible within the depth of focus at [redacted]. The edge riders could be held down by spring pressure and could be held away by magnetic blocks for a couple of millimeters or so, while the film is being wound. If [redacted] inch film is used, one would have [redacted] inch on each edge for the hold down arcs. No vacuum would be required. Some tension is to be desired anyway, which can be applied a fraction of a second after the edge arcs are holding the film down, which then would smooth out wrinkles.

In changing the film, one might run into scratches from the rubbing of the film on the platen. However, this will be the film base, rather than the emulsion, and perhaps a coating could be used to take up the scratching, to be dissolved off in development, which indeed might just be the anti-halation coating anyway.

There appears to be plenty of room left in the compartment for film spools and motors. It probably will be necessary to run the film over rollers to favored locations for the spools, not necessarily in the same plane or tilt as the focal surface. Of course, much room is taken up by the going and coming light rays, but there still seems to be plenty left on either side of the focal surface, and over the top of the primary mirror, as I remember the compartment shape. To accommodate the large primary, you may have to reshape the compartment in the one dimension.

As for weight, if we allow 100 lbs for the primary, 40 lbs. for the shell-lens, 40 lbs for the pair of corrector elements and window, we have a total of 180 lbs for the glass parts. These could be mounted in welded tubular cages of light weight. Indeed, I believe the weight of optical parts could be reduced if absolutely necessary. The diagonal mirror might also weight 30 lbs. or so.

This same optical system when fully optimized might well cover an even larger field than [redacted] degrees, but the primary mirror becomes all the larger. I believe the basic optical system is a good one provided everything possible is squeezed out of the parameters. The thickness of the shell is important and in fact, the thicker the better, if [redacted] lines performance is otherwise endangered. I cannot really estimate the ultimate performance, since only a second or two of arc is involved, but do believe a fully optimized system of this form will be found satisfactory.

Finally, one should compare this very large system with the far more compact all lens systems employing also the same curved field. If only [redacted] lines performance is sought after, then I do believe that a fixed lens system might be designed accomplishing such a result at [redacted]. However, the film would have to have its emulsion on the concave side of the curved focal surface.

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The lens would be subject to vagaries of focal setting due to temperature and pressure changes. Even so, if everything about such a system were optimized, I would suppose that [redacted] lines performance can be achieved.

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The mirror system shown here, on the other hand, though far larger, is fully achromatized and might be expected to give better than [redacted] lines performance on a medium fine grain emulsion at a [redacted] second exposure time or faster.

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The focus can be stabilized against temperature by combining the mount holding the distance between film and mirror of both invar and some stainless tubing. The pyrex primary to begin with will not change much with temperature and there will be no pressure-focus effects at all. It only remains to match the mount to pyrex by the invar-stainless steel combination mentioned. The metal will come to temperature equilibrium very quickly and the thin pyrex primary might be expected to do so quickly also.

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This array, whether in the lens or mirror form, must employ the diagonal mirror. This clearly must be held extremely firmly in its mount. Although in principle, a slight motion of this mirror would provide the IMC, it might be preferable in practice to tilt the whole camera. The window would not share this IMC motion, but the corrector elements would. Although the torix field-flattening element at the slit might be shaped to provide the IMC, I dislike to have any optical surfaces so near to the image surface. To do so invariably degrades the contrast sooner or later, and where we are shooting for [redacted] lines, every such source of scattered light should be eliminated. I much prefer forcing the film to follow the curved surface.

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I doubt very much whether the optical parts of the mirror system will be nearly so sensitive to elevated temperatures as would an all-lens system. However, everything reasonable should be done to keep the mounting at a uniform temperature and to focus accordingly. The quartz window might conceivably carry an infra-red reflecting film that would minimize the radiation imparted to the optical system. It would not be a good idea to introduce any air turbulence inside the optical paths, even at low densities. In this mirror system the light rays go so far before reaching the film, one must be careful to provide a homogeneous medium to prevent heat waves from affecting the [redacted] line performance.

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To sum up, the mirror optical system is by no means an easy thing to build, but it does appear to be feasible. It would be important to settle the matter of ultimate optical performance at the earliest moment before going too far in working on secondary problems. Fortunately, the good performance of the existing SuperSchmidt Meteor Cameras at [redacted] and a [redacted]-degree field would lead one to believe that this system would work very well indeed at [redacted] over a [redacted] degree field.

Sincerely,